Ephemeris of Swift's Comet.—The following elements and ephemeris of Swift's comet, the reappearance of which was announced last week, have been computed by Dr. Berberich, and are published in *Edinburgh Circular*, No. 45. The elements are deduced from the observations:—Mount Hamilton, August 21; Nice (M. Juvelle), August 24; Hamburg, August 25.

Another observation of August 23, made by Mr. J. Witt at the Urania Observatory, Berlin, is closely represented by the ephemeris. Dr. Berberich thinks the comet will possibly belong to the group of periodic comets with short revolution.

Elements.

T = 1895, Sept. 3·3630, M.T. Berlin.

$$\left.\begin{array}{rcl} \omega & = & 179^\circ\ 37'{\cdot}94 \\ \Omega & = & 172\ \ 59{\cdot}65 \\ i & = & 4\ \ 38{\cdot}55 \end{array}\right\}\ \text{Mean Equinox 1895·0.}$$

$$\log q = 0{\cdot}16537.$$

Ephemeris for Berlin Midnight.

1895.	R.A. h. m. s.	Decl. ° ′	log. Δ.	log. r.	Brightness.
Sept. 4	1 0 7	+6 17·3			
6	1 4 3	6 18·0	9·7100	0·1656	1·17
8	1 7 50	6 17·5			
10	1 11 28	6 15·9	9·7071	0·1664	1·18
12	1 14 57	6 13·2			
14	1 18 16	6 9 6	9·7062	0·1679	1·18
16	1 21 25	6 5·1			
18	1 24 23	5 59·7	9·7073	0·1700	1·16
20	1 27 11	5 53·6			
22	1 29 49	+5 46·9	9·7107	0·1727	1·16

The brightness at August 21·5 has been taken as unity.

Comets and the Sun-spot Period.—Since the discovery of the periodicity of the sun-spots, investigations have shown that many terrestrial phenomena are, and others may be, closely allied to it. These are generally looked upon as results due to the variation in the sun. If it were found that comets had an eleven-yearly period, we should have the question before us as to whether this period be the result of this period, or whether the period depended to a certain extent on this periodical cometary influx. If the sun, as has been supposed, were fed, so to speak, with cometary matter, then the spot period would naturally be dependent on some external source of supply such as this. But since the solar atmosphere has a circulation which seems now to have been fairly shown to be the cause of this periodicity, such an outward supply of energy is not thought now to be of such importance as would have been the case some years ago. This does not take away the interest, however, from Herr J. Unterweger's investigation concerning the connection of spots and appearances of comets, but would rather instigate it. The author has, by a strict examination of the elements of the larger periodical comets, obtained a function which can be represented mathematically by a formula, and from which an eleven-yearly period since 1740 can be recognised. From the year 1833, also, the maxima and minima points fall together, without exception, with those of the sun-spot curves. In determining the length of the period, the amplitude of the period was set for each series as a function of the length of the period, and then each value for the duration of the period ascertained. The calculation was so arranged that two neighbouring values, which made the amplitude a minimum, were also determined. The values for the function came out as 8·682, 11·226, 13·365 years, those for the series showing the relative number of sun-spots being 8·721, 11·254, 13·424 years.

To determine also whether the points of maxima and minima for the function were coincident with those for the series showing the sun-spot numbers, the curves drawn from the values derived coincided to such an extent that a secondary maximum could be recognised on both of them in similar positions.

Other results which the investigator indicates as having been shown are:—The identification of the thirty-five-yearly sun-spot period, the function giving larger values in 1778, 1816, 1848 and 1882, and smaller minima in 1764, 1806, 1834 and 1867; the time between two successive maxima being in the mean 34·8 years.

The secular period 1764–1806, with maximum at 1777–80, coincides with a secular maximum of sun-spots and a large *gletscherverstors* which began in 1768 and ended about 1785. The 1806-1834 interval, with a maximum at 1816, corresponds to a maximum of sun-spot and to an intense *gletscherverstors* from 1814 to 1824. The third and fourth periods are also likewise explained.

Cases are also made out for the secular variations in the climate, and a suggestion is thrown out that if we may look upon "Kometen als stark elektrische Massen," then at the times of their maximum number and least distances from the earth, small induced currents may be set up, which will be recorded by the magnetic needle; this latter question has not, however, been investigated.

THE SUN'S PLACE IN NATURE.[1]

XI.

The Clock Rate.

The proper regulation of this clock error and consequent "trail" of the spectrum across the plate parallel to itself are essential to the success of photographs taken by the objective prisms. The spectrum of a bright star must obviously be made to trail more quickly than that of a fainter one, and a shorter exposure is sufficient. Since for the same clock error, and in the same time, a star near the pole will give a shorter trail than one nearer the equator, declination must also be taken into account. Keeping a constant clock error, equal widths of spectrum for stars of different declinations may be obtained by lengthening the time of exposure for stars away from the equator, but in that case, the stars near the pole would be over-exposed in relation to those nearer the equator.

The exposure given to stars of equal magnitudes should evidently be the same, no matter in what part of the sky they may be situated, and the clock error should, therefore, be increased in proportion to the secant of the angle of declination.

The light-ratio of stars being $2{\cdot}512^n$, where n expresses the difference in magnitude, the time of exposure must vary in the same proportion, and the clock error in inverse proportion. Thus, where 5 minutes' exposure is sufficient for a first-magnitude star, 31 minutes is required to obtain a fully-exposed spectrum of a star of the third magnitude. This law, however, only applies to photographic magnitudes, and must be modified according to the type of spectrum or the colour of the star.

The red stars, being much weaker in blue and violet rays than the yellow or white stars, require much longer exposures than white stars of equal magnitude. To obtain a spectrum of β Pegasi extending to the K line, for example, at least three times the exposure required by a white star of similar magnitude must be given.

For conveniently adjusting the exposures, tables have been constructed which show at a glance the position of the regulator for a star of given magnitude and declination.

It is obvious that with an instrument of high dispersion, the number of stars it is possible to photograph is very limited, as the long exposures required for the fainter stars are impracticable, and, even if possible, the definition of the lines would be destroyed by atmospheric tremors.

Hence, it is at present only possible to photograph the spectra of the faint stars on a very small scale. With an objective of 8 inches aperture and 44 inches focal length, and a prism of 13° refracting angle, Prof. Pickering has photographed the spectra of stars down to the eighth magnitude. These spectra are about 1 centimetre long, and a millimetre broad, and though they do not show a very great amount of detail, they are sufficient to reveal the type of spectrum.

With an instrument capable of photographing faint stars, a large number of spectra may be taken at one exposure; but, with the instruments of larger dispersion, this is not generally the case, as there are few bright stars of nearly equal magnitude sufficiently close together.

The Electrical Control.

In consequence of the great accuracy required in the driving of the telescope when long exposures are necessary, the 10-inch equatorial has been fitted with a simple and inexpensive form of electrical control. This is a modification of that designed by Mr. Russell, of the Sydney Observatory.[2] The existing driving gear has been altered so that the driving rod performs its revolution in a second, and the motion is then communicated to the driving screw through a small worm wheel. The driving rod is vertical and in two parts, the lower portion ending in a faced ratchet wheel, 3 inches in diameter, and with 200 teeth. The upper part of the rod ends in an arm at right angles to itself, and this arm carries a ratchet of suitable shape held down by an adjustable spring. An electro-magnet connected with the controlling pendulum, is arranged so as to only permit the ratchet to pass it once a second (see Fig. 42). If the clock be driving too quickly, the ratchet is held until the stop is raised by the pendulum. When held in this way the ratchet is lifted out of the teeth, and the driving clock itself is not affected.

---

[1] Revised from shorthand notes of a course of Lectures to Working Men at the Museum of Practical Geology during November and December, 1894. (Continued from page 425.)

[2] *Monthly Notices*, vol. li. p. 43, 1890-91.

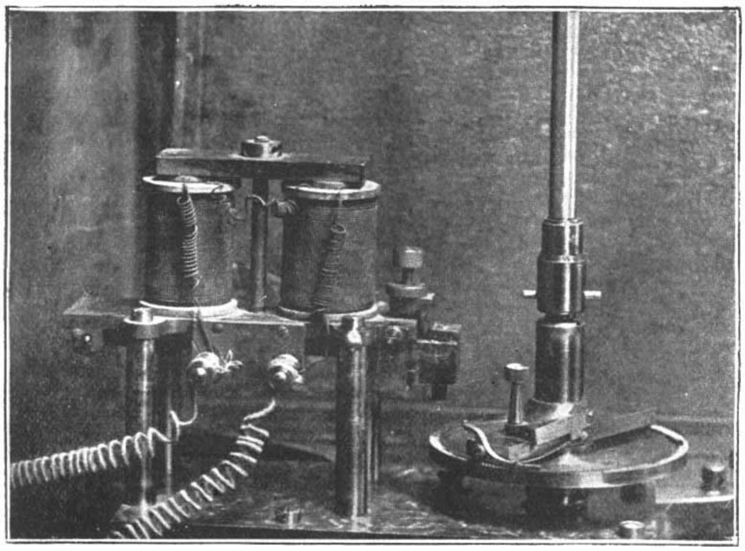
Fig. 42.—Electrical control for 10-inch equatorial.

In order that this form of control may be effective, it is essential that the clock should be going too quickly, as it is only capable of retarding the driving-rod.

The controlling pendulum is, of course, regulated to the rate required for the particular star which is being photographed.

In Mr. Russell's form of control the two parts of the driving rod are connected by friction plates. It was found, however, on testing this arrangement, that when the upper portion was held by the electro-magnet the rate of the governors was seriously retarded; hence I introduced a ratchet wheel, and its working leaves nothing to be desired.

Enlargements of the Negatives.

Many of the negatives taken have been enlarged about nine times on glass, and further copies have been taken on bromide paper, bringing the enlargement up to about twenty-five times the size of the original.

Owing to various causes the photographic spectra obtained by the method of trails show irregularities resembling the lines along the spectrum observed when the slit of a spectroscope is partly clogged with dust. It has been noticed that the period of the irregularities is equal to the time of revolution of the main driving screw of the telescope, and hence they may be accounted for by supposing the driving gear to be mechanically imperfect. In that case some of the parallel lines which, by their juxtaposition form the broadened spectrum, are superposed, while others are drawn apart, thus giving rise to dark and bright lines parallel to the length of the spectrum. These lines are more apparent in the case of bright stars than fainter ones. If the telescope were driven with perfect regularity and the atmosphere were quite steady, we should obtain a spectrum of uniform intensity along its width. This condition has very nearly been obtained in some cases.

The irregularities above described are eliminated in the enlarged negatives by giving them a very slight up-and-down motion during exposure in a direction parallel to the lines of the spectrum. This was originally done by hand, but a negative holder has been constructed in which the necessary motion is given to the negative by a small driving clock.

A diagram of the arrangement is given below. The only drawback to this method is that defects of the film are apt to produce, by a succession of their images on the enlarging plate, lines (generally very faint) which have a semblance of the true spectrum lines.

To distinguish the real lines from the artificial ones, a direct enlargement of the spectrum is made on the same plate alongside the other, the to-and-fro motion being dispensed with. By a comparison of the two enlarged strips, one can see at a glance which are the true lines of the spectrum, and which are those produced by small irregularities on the film. It may be stated that Dr. Scheiner has also used a somewhat similar method to the one described, the only difference being that he caused the plate on which the enlargement was to be taken to have the oscillating motion, instead of the original negative. The method employed by me, though no account of it had been published, had been in use for some time before Dr. Scheiner's method was announced.[1]

My object was not so much to obtain photographs of the spectra of a large number of stars, as to study in detail the spectra of comparatively few; hence many of the stars have been photographed several times with special exposures and foci for different regions of the spectrum.

As in the case of stellar spectra observed by eye, the photographic spectra vary very considerably in passing from star to star.

In the classification of stars adopted from a consideration of the visual observations, only the broader differences in the spectra have been taken into account. Prof. Pickering, however, has suggested a provisional classification in connection with the Henry Draper Memorial photographs of stellar spectra, but this chiefly relates to photographs taken with small dispersion. Now that it has become possible to obtain large dispersion photographs of the spectra, much more detail is revealed, and hence I determined to deal with the presence, or absence, or changes of intensity, of individual lines to a greater extent than Prof. Pickering has done in his observations so far published.

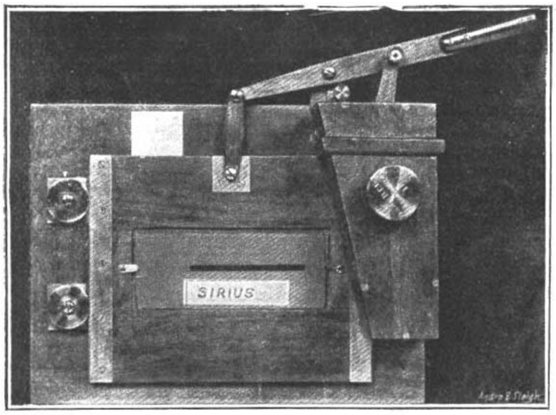

Fig. 43.—Negative holder used in enlarging

In the first instance, I arranged the various stars of which the spectra have been photographed in tables, without reference to any of the existing classsfications, and not taking into account the finer details.

The basis upon which this first grouping was founded is the extent of the continuous absorption at the blue end of the spectrum. Such a distinction was not possible in the case of eye observations, and it is only by photographs that a classification from this point of view can be made.

---

[1] Nature, vol. xlii. p. 303, 1890.

Some spectra show a remarkable continuous absorption either in the ultra-violet or violet, in others this absorption extends to about K, whilst in a third class it reaches as far as G.

These considerations gave four marked groups. Each of these main groups are next sub-divided into sub-groups by the most marked differences in the spectral lines. I do not propose to give the detailed inquiry in this place.

The important fact which stood out when the photographic attack had got so far was that, whether we take the varying thicknesses of the hydrogen lines or of the lines of other substances as the basis for the arrangement of the spectra, it was not possible to place all the stars in one line of temperature, but it was necessary to arrange the stars in two series.

When this sorting was completed, I was in a position to consider the various divisions of the photographic spectra thus arrived at, in relation to the groups which were previously suggested from a discussion of eye observations. It is clear that if I got the same results the first conclusions would be strengthened.

We have, therefore, to inquire how far this condition is satisfied by the mass of new facts at our disposal. This involves the consideration of some points in connection with the meteoritic hypothesis, and it must specially be borne in mind that the fundamental difference between mine and other classifications is that it demands the existence of bodies of increasing as well as bodies of decreasing temperatures.

Since in my classification the connection between nebulæ and stars is insisted on, it was necessary to obtain a spectrum of one of the brightest of the nebulæ as a term of comparison. The nebula of Orion was selected, and a photograph taken with a 30-inch silver on glass reflector in February 1890. This photograph contained 54 lines, which were carefully tabulated for the purposes of the comparison to which reference has been made.

The Complex Origin of the Spectra of Nebulæ.

On the hypothesis, the bright lines seen in the nebulæ should have three origins.

(1) The lines of those substances which occupy the greatest volume (or largest area in a section); in other words, the lines of those substances which are driven furthest out from the meteorites and occupy the interspaces, when possibly they may be rendered luminous by electricity. Chief among these, from laboratory experiments, we should expect hydrogen, and next, from the same experiments, we should expect gaseous compounds of carbon.

(2) We are justified in assuming that the most numerous collisions will be partial ones—grazes—sufficient only to produce comparatively slight rises in temperature. The nebula spectrum, so far as it is produced by this cause, will therefore depend upon the phenomena produced in greatest number, and we may hence expect to find the low temperature lines of various metallic substances.

(3) In addition to the large number of partial collisions there will be a relatively small number of end-on collisions, producing very high temperature,[1] and, so far as this cause is concerned, there will be some lines produced which are associated with very high temperatures.

Combining these conclusions, in the spectra of nebulæ we should expect to find evidence of

Hydrogen and compounds of carbon.
Low temperature metallic lines and flutings.
Lines which are only produced at very high temperatures.

The Passage to Bright-line Stars.

On the hypothesis, the lines seen in the spectra of bright-line stars should, in the main, resemble those which appear in nebulæ. They will differ, however, for two reasons:—

(1) Owing to partial condensation of the swarm the hydrogen area will be restricted, and the bright lines of hydrogen will lose their prominence; the volume occupied by the carbon compounds will be relatively increased, and the brightness of the carbon bands will be enhanced.

(2) On account of the increased number of collisions, more meteorites will be rendered incandescent, and the continuous spectrum will be brighter than in nebulæ.

Stars of Increasing Temperature.

Initially, each pair of meteorites in collision may be regarded as a condensation.

Ultimately, when all the meteorites are volatilised, there will only be one condensation, in the shape of a spherical mass of vapour. Between these points there must be other conditions.

(Stage 1.) At the stage of condensation immediately following that of the bright-line stars, the bright lines from the interspaces will be masked by corresponding dark ones produced by the absorption of the same vapours surrounding the incandescent meteorites. One part of the swarm will give bright lines, another dark lines at the same wave-lengths, and these lines will therefore vanish from the spectrum. The interspaces will be restricted so that absorption phenomena will be in excess, and the first absorption will be that due to low-temperature vapours, that is, fluting absorptions of various metals. The radiation spectrum of the interspace will now be chiefly that of the compounds of carbon. Under these conditions we know from laboratory experiments[1] that the amount of continuous absorption at the blue end will be at a maximum.

(Stage 2.) With further condensation the radiation spectrum of the interspaces will gradually disappear, and the fluting absorptions will be replaced by dark lines, for the reason that the incandescent meteorites will be surrounded by vapours produced at a higher temperature, the number of violent collisions per unit time and volume being now greatly increased. This dark line spectrum need not necessarily resemble that of the Sun.

(Stage 3.) The line absorption and the continuous absorption at the blue end of the spectrum will diminish as the condensations are reduced in number, for the reason that only those vapours high up in the atmospheres surrounding the condensations will be competent to show absorption phenomena, in consequence of the bright continuous spectrum of the still disturbed lower levels of those atmospheres.

Among the more important lines which will disappear at this stage will be those of iron, for the reason that there will be bright lines from the interspaces occupying the same positions as the dark lines produced by the absorption of the vapour surrounding the stones.

The number of violent collisions per unit time and volume being further increased, we should expect the absorption of very high temperature vapours.

The Hottest Stars.

Ultimately, then, we should expect that the order of the absorbing layers will follow the original order of the extension of the vapours round the meteorites in the first condition of the swarm, and the lines seen bright in nebulæ, whatever their origins may be, should therefore appear almost alone as dark lines in the hotter stars, and the hydrogen especially should have its lines broadened with each increase of depth in the atmosphere. The continuous absorption at the violet end of the spectrum will be at a minimum. If, when the hydrogen lines are thick the swarm is not yet completely condensed, that is, if there be nebulous matter surrounding the central mass of vapour, a fine bright line will be seen down the centre of each dark one.

Stars of Decreasing Temperature.

When we consider the cooling condition, that is, what happens when the temperature of the mass of vapour is no longer increased by the fall towards the centre of meteorites composing the initial swarm, we should expect to find the phenomena indicated below.

(Stage 1.) The hydrogen lines will begin to thin out, on account of the diminishing depth of the absorbing atmosphere, and new lines will appear.

The new lines will not necessarily be the same as those observed in connection with the stars of increasing temperature.[2] In the latter there will be the perpetual explosions of the meteorites affecting the atmosphere, whereas in a cooling mass of vapour we have to deal with the absorption of the highest layers of vapours. Those lines which will first make their appearance. however, will be the longest low temperature lines of the various chemical elements.

---

[1] *Roy. Soc. Proc.*, vol. xliii. p. 150.

[1] Lockyer and Roberts-Austen, *Roy. Soc. Proc.*, 1875, p. 344.

[2] *Roy. Soc. Proc.*, vol. xlv, p. 382.

(Stage 2.) The hydrogen lines will continue to thin out, and when the absorption of the hotter lower layers makes itself felt the spectra will show the high temperature spectra of the various chemical elements, showing many more lines. The difference between these and the lines seen in stars of increasing temperature should be one due to the different percentage composition of the absorbing layers, so far as the known lines are concerned.

With this increasing line absorption there will be a recurrence of the continuous absorption in the ultra-violet.

(Stage 3.) With the further thinning of the hydrogen lines and reduction of temperature of the atmosphere, the absorption flutings of the compounds of carbon should come in.

So much, then, for what we should expect, assuming the hypothesis to be true.

I now proceed to show how far these requirements are satisfied by the mass of new facts now at our disposal.

The Actual Phenomena Recorded on the Photographs.

Nebulæ.

The photographs of the spectrum of the Orion Nebula show lines at wave-lengths which approximate very closely to the lines of hydrogen, to flutings which appear in the spectra of compounds of carbon, to a fluting of magnesium at 5006, and to the longest flame lines of iron, calcium, and magnesium.

The chromospheric line designated D_3 has been recorded in the visual spectrum of the Orion Nebula by Dr. Copeland,[1] and the observation has since been confirmed by Mr. Taylor.[2]

The line which is always associated with D_3 in the spectrum of the chromosphere, viz. that at λ 4471 (Lorenzoni's *f*), is also shown in the photograph of the spectrum of the Orion Nebula.

The requirements of the hypothesis with regard to nebulæ are therefore met in every point so far considered by the new facts.

Dividing up the lines into the three groups of origins suggested, we have in the case of the Orion Nebula :—

(*a*) Spectrum of large interspace (= that of non-condensable gases driven out of the meteorites) = lines of hydrogen; flutings of carbon.

(*b*) Spectrum of vapours produced by the large number of partial collisions = fluting of magnesium at λ 5006; low temperature lines of iron, calcium, and magnesium.[3]

(*c*) Spectrum of the vapours produced at a very high temperature by the relatively small number of end-on collisions. The solar chromosphere may be taken as indicating the spectrum associated with this very high temperature = chromospheric lines, D_3 + λ 4471.[4]

Bright-Line Stars.

Prof. Pickering has shown that the Draper Memorial Photographs (copies of which he has very kindly forwarded me) prove that bright-line stars are intimately connected with the planetary nebulæ, the lines in the spectra being almost identical.

The main point of difference is that the chief nebular line near λ 5006 is not seen in the spectrum of bright-line stars, and this no doubt is due to the relative absence of feeble collisions as condensation goes on. The brightening of this line in the spectra of Nova Cygni and Nova Aurigæ, as the stars faded away, is sufficient evidence that it is associated with low temperature, and hence it is not surprising to find that it is absent from the spectra of the bright-line stars, which on this hypothesis are hotter than the nebulæ, since they are more condensed.

I have stated that we should expect the hydrogen lines to be fainter, and the carbon flutings, and the continuous spectrum to be brighter than in nebulæ.

(*a*) The hydrogen lines are decidedly less prominent. Indeed they were not recorded at all in the eye observations of γ Argûs (Arg.-Oeltz., 17681), of Wolf and Rayet's second and third stars in Cygnus,[1] but they are shown in Prof. Pickering's photographs.

(*b*) In my previous discussion of these bodies[2] I showed that there was evidence of a very considerable amount of carbon radiation in the visible region of the spectrum. Subsequent work and an examination of Prof. Pickering's photographs have strengthened this view.

(*c*) There can be no question as to the continuous spectrum being brighter in bright-line stars than in nebulæ.

Stars of Increasing Temperature.

(Stage 1.) We should expect the spectra to show—

(*a*) Absence of bright lines.

(*b*) The presence of dark metallic flutings.

(*c*) The presence of bright carbon flutings.

(*d*) Continuous absorption in the violet.

Many of the stellar photographs answer these requirements.

(*a*) They show no bright lines under normal conditions, but if the stars are variable, the disturbances which bring about the change of luminosity at maximum, produce bright lines in the spectrum as in the case of the spectrum of Mira Ceti photographed by Prof. Pickering.

(*b*) Dark flutings have been photographed in several spectra.

(*c*) The photographs appear to show the actual presence of carbon radiation; further photographs are being obtained to carry on the inquiry.[3]

The stars of this class which have already been photographed at Kensington are well advanced in condensation, as indicated by the numerous dark lines, and all the flutings, both bright and dark, are confined to the region less refrangible than G. We should therefore not expect to get the more refrangible carbon flutings. It is among the least condensed stars that we should expect the bright carbon to be more manifest, and, indeed, in the spectrum of Mira Ceti photographed by Prof. Pickering, there is strong evidence of the presence of one of the more refrangible carbon bands commencing at λ 4215.

(*d*) The photographs fully demonstrate that there is a very considerable amount of continuous absorption in the ultra-violet or violet.

It must be added that the sequence of the spectra photographed resembles that deduced from eye observations, and the wonderful thing is that the observations of Dunér will bear the severe test which has thus been applied to them.

(Stage 2.) At this stage we should expect—

(*a*) Diminution in the amount of continuous absorption.

(*b*) Spectrum consisting of dark metallic lines, but possibly differing from the solar spectrum.

These conditions are fulfilled by the stars of which α Tauri and γ Cygni may be taken as types. The continuous absorption is least in the latter. These spectra show numerous metallic lines, but they do not exactly resemble the solar spectrum. The hydrogen lines are comparatively thin, while other lines have very different intensities as compared with lines in the solar spectrum.

In these stars we have to deal with the varying volatilities of the meteoretic constituents of the swarm, while in the case of stars which are cooling we have to deal with successive combinations rendered possible by the fall of temperature in a gaseous mass. Hence differences in the spectra are to be expected.

(Stage 3.) The phenomena which would be expected on the hypothesis, at this stage, are fully satisfied by such stars as α Cygni, β Orionis, ζ Orionis, ε Persei. In these stars there is no continuous absorption in the violet or ultra-violet, and the spectrum is one with simple line absorption, the iron lines quite disappearing after such a star as α Cygni is passed. The new lines which now make their appearance include the chromospheric line at λ 4471, and possibly a few others. It is important to note that the photographic region of the spectrum of the chromosphere has not yet been fully investigated, and hence a fair comparison with the spectra of these stars in the region F to K is not yet possible. M. Deslandres and Prof. Hale have photographed the chromospheric spectrum in the region more refrangible than H, but have not as yet published any account of the spectrum in the region now under discussion.

---

[1] *Monthly Notices*, vol. xlviii., p. 360.

[2] *Ibid.*, vol. xlix. p. 124.

[3] I have previously given evidence deduced from eye observations, indicating the presence of other low temperature flutings of manganese and magnesium.

[4] Since the lectures were delivered (and in this I summarised a paper I had previously sent in to the Royal Society), this part of the hypothesis has been enormously strengthened by the discovery of a new series of gases which the spectrum indicates are associated with the one giving the line D_3 which I discovered in 1868 and named helium. These new gases contain many lines in addition to D_3 and 4471, which appear both in the solar chromosphere and nebula of Orion and stars of increasing temperature.

[1] *Roy. Soc. Proc.* vol. xliv., pp. 33-43.

[2] *Ibid.*

[3] Subsequent eye observations by myself and Mr. Fowler seemed to leave no doubt as to the presence of these bright carbon flutings (*Roy. Soc. Proc.*, vol. xlvii. p. 40). Dr. Copeland had previously made important observations of "Nova" Orionis with reference to this point (*Monthly Notices*, vol. xlvi. p. 112), and he identified one of the bright bands as "the great hydrocarbon band seen in the spectrum of every comet that has been examined under favourable circumstances." Referring to his observations of α Orionis, Mr. Maunder ("Greenwich Spect. Observations," 1889, p. 22) states that "the carbon band at 5164 was coincident (within the limits of observation with this dispersion) with the bright space towards the blue of Dunér's band 7."

The Hottest Stars.

The conditions required by the hypothesis with regard to the stars at this stage are satisfied by such stars as ζ Cassiopeiæ and α Andromedæ.

In these stars we have—

(*a*) Broad lines of hydrogen, and

(*b*) Other absorption lines, chiefly of untraced origins, agreeing in position with some of the bright lines which appear in nebulæ.

It will be seen, then, that these considerations of the conditions of increasing temperature demanded by the hypothesis, have enabled us to determine that a long series of stellar spectra is in all probability a series in *ascending* order of temperature. All the phenomena we should expect, on the hypothesis, are met with among the photographs.

We have next to consider the phenomena connected with stars of decreasing temperature.

Stars of Decreasing Temperature.

(Stage 1.) With the failure of the supply of meteorites falling into the now vapourised mass, cooling will commence, and the longest lines in the spectra of the various chemical elements should make their appearance. This condition is met with and is well evidenced by the iron lines in the spectrum of Sirius.

(Stage 2.) The conditions at this stage of cooling are satisfied by δ Cassiopeiæ, β Cassiopeiæ, α Canis Minoris. In these stars we get, in addition to fairly broad lines of hydrogen, nearly all the lines which appear in the solar spectrum, and these, it is well known, agree in the main with the arc spectra of the various chemical elements.

(Stage 3.) Such stars as Capella and Arcturus represent the conditions which are required by the hypothesis at this stage of cooling. The metallic line absorption is again at a maximum, and we find the lines of the various chemical elements similar to those seen at Stage 2 of the ascending series, but with different intensities and with different amounts of continuous absorption at the violet end of the spectrum. This difference, so far as the known lines are concerned, will be due to a different percentage composition of the absorbing mass of vapour.

Continuous absorption in the violet recommences at this stage. There is undoubted evidence of carbon in the solar spectrum, and in the spectrum of Arcturus—the only star which has yet been investigated with special reference to this point.

Hence, it seems probable that "the indications of carbon will go on increasing in intensity slowly, until a stage is reached, when, owing to the reduction of temperature of the most effective absorbing layer, the chief absorption will be that of carbon."

It is evident that all such stars will be dim, and hence their spectra have not been met with in this preliminary survey of the photographic spectra of the brighter stars.

General Results of the Discussion.

The general result of the above discussion then, as far as it goes, is as follows:—Among the 171 stars already considered there are really two series of spectra, one representing the changes accompanying increase of temperature, while the other represents the effects of decreasing temperature. The fundamental requirement of the meteoritic hypothesis is, therefore, fully justified by the discussion of the photographs.

A very important point in connection with the two series of successive spectra is that one spectrum, such as that of α Andromedæ, possesses characteristics common to both, and we might, therefore, connect the two series together by this spectrum. In that case we should find, if we commence with the first spectrum in Series 1, say that of α Herculis, that the continuous absorption diminishes and that the breadth of the hydrogen lines regularly increases, until such a spectrum as that of α Andromedæ is reached. Then the condition would be reversed, the breadth of the hydrogen lines diminishing and the continuous absorption in the ultra-violet increasing in extent until such a star as Arcturus is reached.

It may be stated finally that the sequence now determined from the photographs follows exactly the same order as the groups originally suggested by the hypothesis, from a discussion of the eye observations. That is, it is not necessary to interchange any of the groups in order to obtain agreement with the photographic results. J. NORMAN LOCKYER.

SCIENCE IN THE MAGAZINES.

PROFS. WEISMANN, Haeckel, and Karl Pearson will probably have something to say in reply to a paper which Dr. St. George Mivart contributes to the *Fortnightly*. The paper deals with what is described as "Denominational Science," in which dogma takes the place of facts, and persuasions are given out as if they were demonstrated truths. Dr. Weismann comes under Dr. St. George Mivart's displeasure in this regard; and a noteworthy characteristic of his is said to be "the confidence with which he propounds hypotheses which are either purely imaginary, or are only supported by an infinitesimal basis of fact, and the readiness with which he comes forward with a fresh gratuitous hypothesis, to replace others which have been refuted by newly-discovered truths." Prof. Haeckel is taken to task for the opinions expressed in his book on "Monism," lately translated into English. The bearing of Dr. St. George Mivart towards the book is indicated by the remark which opens the attack upon some of the points in it. We read: "It is difficult to say whether this small volume is more remarkable for the self-conceit and empty dogmatism, or for the ignorance it displays—ignorance concerning the most fundamental questions of which its treats." To assess these remarks at their proper value, it is necessary to read the article containing them, and the work to which they refer. Prof. Karl Pearson completes the trio upon whose views Dr. St. George Mivart outpours the vials of his wrath. His "Grammar of Science," and his remarks, in the *Fortnightly*, on Lord Salisbury's Oxford address, are given as evidence that "we have in England a denominational writer only second in self-confident dogmatism to Haeckel." All the members of the trio are held up as awful examples of "an unconscious slavery of the intellect to the mere faculty of the imaginal tion, and the consequent presentation of shallow and illogical imaginary phantasms as deep and far-reaching intellectual truths in the form of baseless dogmas of denominational science." Huxley and Karl Vogt are compared by Prof. Haeckel in the *Fortnightly*, the former being given a higher place than the latter, both as regards his philosophical reasonings, and because he showed a much deeper insight into the essence and import of scientific things. Two pages of the six, which form Prof. Haeckel's notice, are taken up with a denunciation of Prof. Virchow's antagonism to Darwinism, and the theory of descent, especially with reference to the most important deduction from the theory—the descent of man from the ape. Virchow's dissent in this matter is used as one of the sticks with which Mr. F. H. Hill belabours agnosticism, and Huxley's support of it, in the *National*, under the title, "Gaps in Agnostic Evolution."

Mr. Herbert Spencer continues his analysis of "Professional Institutions," in the *Contemporary*, the evolution of the biographer, historian, and man of letters being traced this month. "The primitive orator, poet, and musician," says Mr. Spencer, "was at the same time the primitive biographer, historian, and man of letters. The hero's deeds constituted the common subject-matter; and taking this or that form, the celebration of them became, now the oration, now the song, now the recited poem, now that personal history which constitutes a biography, now that larger history which associates the doings of one with the doings of many, and now that variously-developed comment on men's doings, and the course of things which constitute literature." Thus arose the rudiments of biography, history, and literature; and many facts illustrative of this early development are cited. Fiction developed out of biography and history, and gradually a class of story-tellers became differentiated. Indeed, for a time after fiction comes into existence, it is still classed and believed as biography. In our own times, we find